LIST OF FIGURES AND TABLES

Figures

Tables

1.0 INTRODUCTION AND BACKGROUND

1.1 Introduction

This report is Volume I of the combined Remedial Investigation/Feasibility Study (RI/FS) Report for Operable Unit 4 (OU4) of the Libby Asbestos Site in Libby, Montana ("the Site"). Volume I is the Remedial Investigation (RI), Volume II is the Feasibility Study (FS). The primary purpose of the RI Report is to present a comprehensive description of the nature and extent of contamination in OU4 and, along with the Baseline Risk Assessment (BRA), present estimates of the risks to human health and the environment posed by the contamination. This information is incorporated into the FS Report, where a systematic analysis is performed to determine the need for, and scope of, remedial action. In other words, the RI and BRA Reports present an *assessment* of risks; the FS Report presents an analysis of how those risks could be *managed*. The overall objective of the RI/FS process is not the unobtainable goal of removing all uncertainty, but rather to gather information sufficient to support an informed risk management decision.

Comment [I1]: Good – sets forth clear expectations.

Following completion of the RI/FS Report, the Environmental Protection Agency (EPA) will prepare a Proposed Plan for public comment. The Proposed Plan will describe EPA's proposed approach for managing risks in OU4, allowing the public formal input before a final decision is made. Following completion and analysis of public comment, EPA will publish a R ecord of Decision that summarizes the information in the RI/FS and sets forth EPA's decision for remedial action.

To the degree practicable given the unique conditions and challenges of the Libby Asbestos Site, the RI/FS was conducted in accordance with EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, OSWER Directive 9355.3-01.

Comment [I2]: Seems alarming. Are there significant, potentially problematic deviations from the guidance?

1.2 Site Background and Summary

Through 1990, Libby, Montana contained a vermiculite mine and associated processing operations that produced a large amount of the world's supply of vermiculite. The vermiculite deposit is contaminated with a virulent form of amphibole asbestos (Libby amphibole). Asbestos is a known carcinogen and is associated with a multitude of respiratory health effects including asbestosis, lung cancer, and mesothelioma. For decades, while the mine operated and after its closure, contaminated vermiculite and waste materials were ubiquitous in the Libby environment. Workers were exposed to contaminated materials at the mine and processing facilities; they transported contaminated dust to their homes on clothes and equipment; and vermiculite and contaminated waste rock in varying forms was used in soils (e.g. as fill or an amendment), construction materials, and for insulation all around the town.

In 1999, in response to media reports describing a high rate of asbestos related deaths in Libby, EPA Region 8 dispatched an emergency response team to investigate the situation. Originally believed to be a problem limited to vermiculite workers, it soon became evident that the scope of the problem was significantly larger. Subsequent environmental investigations and health screenings in 2000 and 2001 showed that many areas around Libby were contaminated with Libby asbestos and that a large percentage of area residents, many with no association to vermiculite mining or processing, showed symptoms of asbestos exposure and disease.

EPA began Superfund emergency response removal actions in 2000, focusing first on larger source areas and areas of potential public exposure (such as former vermiculite processing areas, local ball fields, and schools), then transitioning in 2002 to address individual homes and businesses. These emergency response removal actions continue today. The detailed rationale for, and nature of, the emergency response removal actions is discussed in the original Libby Action Memorandum and subsequent amendments (EPA 2000, 2001, 2002, 2005). The Site was listed on the National Priorities List (NPL) in October 2002. Remedial Investigation activities were also initiated in 2002 and have continued concurrently with cleanup activities since.

1.3 Description of OU4

Superfund sites are often divided into Operable Units (OUs) in order to expedite actions at discrete areas or for cost accounting purposes. Currently, the Libby Asbestos Site is divided into seven OUs:

- OU00. OU00 represents a "site-wide" operable unit and includes removal assessment and removal actions conducted anywhere at the Site not specifically directed toward a separate OU. This primarily includes removal assessment and removal actions conducted at residential, commercial, and public properties in the Libby area.
- OU1. OU1 represents the former Export Plant, defined geographically by the property boundary of the parcel that included the former Export Plant.
- OU2. OU2 represents an as yet undefined geographic area surrounding the former Screening Plant. EPA expects to define the geographic extent of this OU in the future based primarily upon the extent of contamination associated with the former Screening Plant.
- OU3. OU3 represents an as yet undefined geographic area surrounding the former vermiculite mine and Rainy Creek Road. EPA expects to define the geographic extent of this OU in the future based primarily upon the extent of contamination associated with the former vermiculite mine and Rainy Creek Road.
- OU4. OU4 represents a second "site-wide" operable unit which includes investigations and remedial actions conducted anywhere at the Site not specifically limited to a separate OU. This primarily includes RI/FS activities and remedial actions conducted at residential, commercial, and public properties in the Libby area.
- OU5. OU5 represents the former Stimson Lumber Mill, defined geographically by the property boundary of the parcel.
- OU6. OU6 represents the rail yard owned and operated by the Burlington Northern and Santa Fe Railroad (BNSF), defined geographically by the property boundaries of BNSF and extent of contamination associated with the rail yard.
- OU7. OU7 represents the area of Troy, MT and includes all actions specifically addressing Troy.

Geographically, the RI/FS Report for OU4 will focus on residential and commercial properties in the general area of Libby. A "Libby study area boundary" for OU4 was established in 2002 that encompasses most of the populated areas in and around Libby. The rationale for the study area is discussed more in Section 7. However, the report is intended to address issues that are present site-wide. As such, the report will provide the basic rationale used to assess and manage risks for the entire Site. For other OUs (especially OU7, Troy and OU3, the mine and mine road) and unique properties, additional reports and administrative documents will be prepared as necessary to address their specific conditions, using the information presented in the OU4 RI/FS and future Record of Decision for OU4 as a foundation.

1.4 Site Team

The RI/FS Report and much of the background information discussed within the report was developed and written by various members of the Libby Site Team. The primary team members and their roles are presented below:

- EPA Region 8. Overall responsibility for Superfund response actions at the Site. Primary author of the RI/FS Report.
- U.S. Department of Transportation, Volpe Engineering Center (Volpe). Through a site-specific interagency agreement, provides administrative, engineering, scientific, and contractual and technical support to EPA. Manages database housing Libby analytical data. Reviewer of the RI/FS Report.
- CDM Federal Programs, Inc. Provides engineering, scientific, and other technical support to both Volpe and EPA, including procurement and management of laboratories that analyze environmental samples from Libby. Conducted or managed nearly all sample collection activities at the Site. Produced tables, figures, and text for the RI/FS Report, generally as noted within the report. Primary author of numerous technical documents cited in the RI/FS report. Reviewer of the RI/FS Report.
- Syracuse Research Corporation (SRC). Provides scientific and risk assessment support to EPA. Produced tables, figures, and text for the RI/FS Report, generally as noted within the report. Primary author of the BRA and other technical documents cited in the RI/FS. Reviewer of the RI/FS report.
- United States Geological Survey, Denver Federal Center (USGS). Through an interagency agreement with EPA, provides scientific and sample analysis support to EPA. Primary author of technical documents cited in the RI/FS. Reviewer of the RI/FS report.
- Montana Department of Environmental Quality (MDEQ). Through a cooperative agreement with EPA, lead agency for investigation of Troy, MT. Reviewer of the RI/FS report.
- Agency for Toxic Substances and Disease Registry (ATSDR). Federal agency tasked with evaluation and development of registries associated with public health effects at Superfund Sites, including Libby. Primary author of technical documents cited in the RI/FS. Reviewer of the RI/FS report.

2.0 SITE DESCRIPTION

2.1 Site Location

The Libby Asbestos Site is located in Lincoln County, Montana and includes areas in and around the towns of Libby and Troy. The area is remote. From Libby, it is approximately ninety miles to the nearest city of Kalispell, Montana. The site lies primarily within Sections 3 and 10, T30N, R31W of the Libby Quadrangle. A map showing the location of Libby and Troy is shown in Figure 2-1.

2.2 Physical Description

2.2.1 Physical Setting

Libby is situated along the Kootenai River, at the confluence of several smaller creeks, in a relatively narrow river valley. Mountains and National Forest surround the Libby valley on all sides: the Cabinet Mountains to the south, the Purcell Mountains to the north, and the Salish Mountains to the east. The elevation of Libby is approximately 2,000 feet above sea level. The area is primarily coniferous forest and heavily vegetated.

2.2.2 Land Use and Typical Construction

The town consists of a small "downtown" core with populated areas spreading in several directions primarily along highways and stream valleys. Businesses are focused in the downtown core and along U.S. Highway 2 and State Highway 37. An area photo is shown in Figure 2-2. The size and construction of typical residential and commercial structures in the area varies considerably, but there are numerous older buildings in various states of disrepair. Roughly 78% of residential properties were built prior to 1990 and 40% were built prior to 1960 (U.S. Census Bureau, 2004). Analysis of local tax records and other information suggests there are approximately 4,000 individual residential, commercial, and public properties in the general Libby area (CDM, 2005a). Site inspections by EPA indicate the presence of significant numbers of properties with "non-standard" construction, deteriorating conditions, and code violations. Most residential yards are grass covered and vegetated, but bare or thin areas are not uncommon.

2.2.3 Geology and Soils

The mountains surrounding Libby are generally composed of folded, faulted, and metamorphosed blocks of Precambrian sedimentary rocks and minor basaltic intrusions. Primary rock types are meta-sedimentary argillites, quartzites, and marbles. (Ferreira et al. 1992). Soils in the area are largely derived from the Precambrian rocks. These rock units break down to form loamy soils composed of sand and silt with minor amounts of clay. The Libby valley area is somewhat enriched in clays due to its river valley location. The dense forest of the region contributes organic matter to the soil. Much of the original soil in the area now occupied by the town of Libby has been modified by anthropogenic factors. These factors include addition of vermiculite from the Rainy Creek Complex to the soil, reworking of the soil during construction, road building, railroad operations, gardening, and other activities. Soils generally vary in color from tan to gray to black.

Excluding vermiculite related materials that may be present, X-ray diffraction (XRD) analyses by the USGS of shallow, sub-surface soils from more than 10 sites in the Libby area show that they are comprised of major (>20%) quartz, minor (5-20%) muscovite (and/or illite) and albitic feldspar, trace (<5%) orthoclase, clinoclore, non-fibrous amphibole (likely magnesiohornblende), calcite, amorphous material (probably organic) and possible pyrite and hematite. Other minerals will be present at levels below 0.5 percent and are generally not detectable by routine XRD analysis. These mineral components represent the average components for the area and will vary to some extent depending on location and history. Surface soils contain the above components with the addition of more organic material.

2.2.3 Climate

Libby has a relatively moist climate, with annual precipitation in the valley averaging slightly over 20 inches (approximately 60 inches of snowfall).. Surrounding higher elevations receive significantly more precipitation. During the winter months, moist Pacific air masses generally dominate, serving to moderate temperatures and bring abundant humidity, rain, and snow. Colder, continental air masses occasionally drop temperatures significantly, but generally only for shorter periods. The average temperatures in December and January are 25-30 degrees F. Snow cover and saturated soils are common in the valley from approximately December to March. During summer, the climate is warmer and dryer, with only occasional rain showers and significantly lower humidity and soil moistures. High temperatures of 90+ degrees F are common. The average temperature in July is approximately 65-70 degrees F. Spring and fall are transition periods.

Due to its valley location along the Kootenai River and downstream of the Libby dam, fog is common in the Libby valley. This effect is most pronounced during winter and in the mornings. Inversions, which trap stagnant air in the valley, are also common. Winds in the Libby valley are generally light, averaging approximately 6-7 miles per hour. Prevailing winds are from the WNW, but daily wind direction is significantly affected by temperature differences brought about by the large amount of vertical relief surrounding the area.

2.3 Sociological Description

2.3.1 Population and Trends (U.S. Census Bureau 2004)

Based on the most recent population estimates available, approximately 2,600 people reside within the city limits of Libby, and approximately 11,000 people reside in the general area of Libby (zip code 59923), which includes the populated areas outside the city limits. Approximately 1,000 people reside within the city limits of Troy.

Some notable trends and statistics:

- The median age of residents of Lincoln County is approximately 42.
- Approximately 25% of residents are under the age of 18.

- Approximately 20% of Lincoln County residents 25 years or older do not have a high school diploma.
- The median household income in 2002 was approximately $28,000, among the lowest in Montana and far below the national average. Approximately 14% of families live below the poverty level.
- The unemployment rate in Lincoln County has stayed between 11% and 15% for several years and is generally the highest rate in the State of Montana. The largest historic employers in Libby, the former vermiculite mine and the former Stimson Lumber Mill, have closed, resulting in the loss of hundreds of jobs over the past several decades.
- The population of Lincoln County Libby is relatively stable. For instance, in 2000, nearly 18% of households reported living in the same housing unit since 1970. During a health screening conducted by ATSDR in 2000, roughly 74% of those surveyed reported living in Libby area for more than 15 years (ATSDR 2001).

2.3.2 Important Sociological Factors

There are a number of sociological factors that may be associated with impacts to respiratory health. Three important factors include smoking, obesity, and air quality.

- Smoking. During the health screening conducted ay ATSDR in 2000, roughly 54% of males and 45% of females reported being a current *or* former smoker. However, roughly 20% of all respondents reported being current smokers, which is similar to state and national averages (ATSDR 2001) (CDC 2002). Smoking is known to cause lung cancer and other respiratory ailments. Smoking has been linked to an increased chance of developing asbestos-related disease, but has not been specifically associated with an increased chance of developing the pleural lung abnormalities and disease associated with exposure to Libby asbestos.
- Obesity. During the health screening conducted by ATSDR in 2000, roughly 31% of males and 34% of females had a body mass index of 30 or higher, which is generally considered obese (ATSDR 2001). This is considerably higher than state and national averages of approximately 18-21% (CDC 2001).

Comment [13]: Explain how this factors into respiratory health.

- Air quality. Census 2000 indicated that approximately 40% of Lincoln County residents utilized wood as a heating source (U.S. Census Bureau 2004). Historically, the amount of wood burning was likely significantly higher. Wood burning and other industrial emissions (e.g. the lumber mill), coupled with the climatologic conditions discussed in Section 2.2.3, have affected air quality in Libby for decades. In 1990, EPA and the State of Montana classified Libby as a moderate non-attainment area for exceedances of national PM-10 standards (particulate matter less than 10 microns in diameter). Particles from wood smoke were identified as the primary constituent. In 2004, EPA and the State of Montana amounced that Libby also exceeded the newer (1997) national standard for PM-2.5 (fine particulate matter less than 2.5 microns in diameter). PM-2.5 is generally accepted to significantly impact respiratory health. Libby was the only area in the western U.S. outside of California to exceed the PM-2.5 standard. Sampling in the Libby area has indicated that wood burning is also the biggest contributor of PM-2.5. Various programs have been instituted to reduce PM levels, including wood stove change outs.

2.4 Site History

2.4.1 General History

Early settlers began establishing ranches in the Libby area in the 1880s in hopes of taking advantage of the anticipated arrival of the Northern Pacific Railroad. The railroad was the determining factor of the location of present-day Libby. In 1890, the railroad made surveys for its path that determined the location of the town. The basic setting has remained the same since.

The timber industry was a major foundation of Libby's economy for much of its history. The first sawmill was built in the winter of 1891-1892 near present day downtown Libby. In 1906, the Dawson Lumber Company built a modern sawmill bringing workers and their families to the town in greater numbers. Many built homes and decided to make Libby their permanent home. In 1911, J. Neils and Associates bought the Dawson Lumber Mill. The J. Neils Lumber Company grew and the town prospered as well, with as many as 1,000 people employed in Libby in the early 1900s. The J. Neils operations were eventually purchased by Champion International, and later, the Stimson Lumber Company. Operations continued under both companies through the 20th century with varying success and pace. Due to dwindling resources, economic conditions, and other factors, Stimson finally closed the mill permanently in early 2003. The property was donated to Lincoln County and is currently being considered for redevelopment.

Construction of Libby Dam, northeast of Libby, was also a significant impact on Libby's history and economy. Construction on the dam began in 1966 and was completed in 1972.

2.4.2 History of Vermiculite Operations

Numerous hard rock mines have operated in the Libby area since the 1880s, but the dominant impact on Libby has been from vermiculite mining and processing. Prospectors first located vermiculite deposits in the early 1900s on Rainy Creek northeast of Libby. Edward Alley, a local rancher, was also a prospector and explored the old gold mining tunnels and digs in the area. Reportedly, while exploring tunnels in the area, he stuck his miner's candle into the wall to chip away some ore samples. When he retrieved his candle, he noticed that the vermiculite around the candle had expanded, or "popped," and turned golden in color. In 1919, Alley bought the Rainy Creek claims and started the "Zonolite Company." While others thought the material was useless, he experimented with it and discovered it had good insulating qualities. Over time, vermiculite became a product used in insulation, plaster, and to lighten garden soil. Many people used vermiculite products for insulation in their houses in Libby and in their gardens. In 1963, the W. R. Grace Company (Grace) bought the mine and associated processing facilities and operated them until 1990. Up until the closure, Libby produced an estimated 80% of the world's supply of vermiculite. Vermiculite was used in a variety of applications including insulation, feed additives, fertilizer/soil amendments, construction materials, absorbents, packing materials, and others.

Operations at the mine included blast and drag-line mining, dry milling of the ore (through 1985), and wet milling (from 1975 until closure in 1990). After milling, concentrated ore was transported down Rainy Creek Road by truck to a screening facility (known today as the former Screening Plant) located along Montana Highway 37 at the confluence of Rainy Creek and the Kootenai River. Here

Comment [14]: Dates overlap - should explain.

the ore was size sorted and transported by rail or truck to processing facilities in Libby and nationwide. At the processing plants, the ore was expanded or "exfoliated" by rapid heating, then exported to market via truck or rail. Historic maps show the location of "Zonolite Company" processing operation at the edge of the lumber mill, near present day Libby City Hall. This older processing plant was taken off line and demolished sometime in the early 1950s. The other processing plant (known today as the former Export Plant), was located near downtown Libby near the Kootenai River and Highway 37. Expansion operations at the former Export Plant ceased sometime prior to 1981, although the area was still used to bag and export milled ore until 1990.

After operations ceased, Grace completed reclamation of the vermiculite mine. Reclamation included demolition of existing facilities and standard land re-contouring and re-vegetation. The former Screening Plant was sold and converted into a nursery and was used for that purpose until 2000. The former Export Plant was converted into a lumber business and was used for that purpose until 2001.

Over the course of Grace's operation in Libby, invoices indicate shipment of nearly 10 *billion* pounds of vermiculite from Libby to processing centers and other locations. Most of this was shipped and used within the U.S. Nearly all of this material ended up in a variety of commercial products that were marketed and sold to millions of consumers. Libby vermiculite is an issue that is national in scope.

In Libby, the sheer volume of contaminated material disturbed, processed, shipped, discarded, and used locally led to a wide variety of releases and areas of contamination. In addition to contamination directly related to vermiculite processing operations (such as aerial releases, spillage, and tramp dust contamination of people and equipment), waste products and off-specification materials were made available to the general public on a large scale. The combination of these factors has resulted in a large number of contaminated areas which have served as ongoing source of contamination and exposure. Some of the more public source areas include:

- The mine itself and surrounding area, including Rainy Creek Road.
- Timber at or near the mine.
- The former screening plant and surrounding area
- The former export plant
- The BNSF rail yard
- The boat ramp and public park adjacent to the former export plant
- The ball fields adjacent to the rail yard and export plant
- The middle school and high school tracks and surrounding areas
- The road shoulders of Montana Highway 37
- The Cabinet View Country Club greens and tee boxes
- The St. Johns Lutheran Hospital helipad
- The compost pile at the Lincoln County Landfill
- A former landfill located on north side of the Kootenai River
- A former nursery located on the former Stimson Mill property
- J. Neils Park

In addition to these locations, vermiculite products and wastes were used in thousands of private residences, businesses, and public buildings across the Libby area. Vermiculite insulation, both commercially purchased and or obtained otherwise, was used at a high rate in Libby buildings. Commercial vermiculite products and waste materials were used as soil amendments, construction materials, and as fill. In the course of Superfund investigations, EPA has encountered vermiculite used as an additive in mortar, plaster, and concrete; as insulation in attics and walls; in soils at depth around septic tanks, tree roots, underground pipe trenches, building foundations; and in surface soils in gardens, yards, driveways, and play areas.

Over time, this combination of sources and releases led to an extremely high number of exposure pathways to Libby residents. Many of these pathways no longer exist or are likely considerably reduced in magnitude, but many were still present when EPA began emergency response in 2000. Some remain today.

A map showing locations of some larger known source areas is shown in Figure 2-3.

2.4.3 History of EPA/Regulatory Involvement

Insert a brief discussion on early investigations, air program, reclamation bond release, Superfund response, litigation. current status.

3.0 PREVIOUS INVESTIGATIONS

Throughout the history of EPA's involvement at the Libby Asbestos Site, and even before, numerous investigations related to vermiculite and asbestos occurred. It is impossible to detail the results of each of these investigations in one document. Similarly, it is impossible to present all of the data collected by EPA at Libby in written form. Since 1999, EPA has analyzed over 80,000 separate environmental samples in and around Libby. These include air samples, dust samples, bulk material samples, and soil samples. Unlike most chemical analyses, the results of asbestos analyses are not simple numbers, but rather volumes of information that are necessary to interpret the samples correctly. The database created to store Libby data (Libby2) contains hundreds of thousands of separate records and occupies an entire server capable of storing 1.2 Gigabytes of information. Nearly all EPA collected data is stored in this central location.

In this RI Report, only the most relevant studies and data are presented in detail. Wherever necessary, the report will reference separate, more detailed documents and provide the queries used to extract the data of interest from Libby2. A general discussion of the larger, most directly applicable studies is presented below. Additional detail and information is found later in the report as appropriate.

3.1 Investigations Prior to EPA Superfund Response

3.1.1 Studies of Libby Vermiculite Workers

Researchers from McGill University (McDonald 1986) and the National Institute for Occupational Safety and Health (Amandus 1987a-c) conducted studies in the early 1980s that documented substantial asbestos exposures and increased disease and mortality rates among a large cohort of current and former W.R. Grace workers in Libby. These studies established unequivocally that exposure to the asbestos found in Libby vermiculite causes significant respiratory health impacts.

3.1.2 W.R. Grace Studies

Throughout its operational history in Libby, W.R Grace conducted or commissioned a number of studies and sampling events related to Libby vermiculite. These included sampling events aimed at assessing the asbestos content of various vermiculite products and wastes, numerous sampling events in Libby and in other locations aimed at assessing exposures to workers and others handling Libby vermiculite products or wastes, and other scientific studies related to the topic. During initial legal and administrative proceedings related to EPA's Superfund Response, W.R. Grace provided EPA with much of this information. These reports and memorandums are too numerous to mention here, but many are referenced later in the RI.

Among other things, these studies showed conclusively that Libby vermiculite is contaminated with asbestos (generally called tremolite asbestos in these reports) and that individuals handling vermiculite products and wastes may have exposures to asbestos that are higher than existing regulatory standards, many of which have since been lowered substantially.

3.2 EPA Superfund Response Investigations

3.2.1 Phase I

After mobilizing to Libby in late 1999, the first major sampling event EPA planned and implemented was denoted as "Phase I." This sampling was intended as a rapid, pilot scale, area-wide assessment of various environmental media (soil, dust, bulk materials and air) to determine if Libby asbestos was present in those materials. These results would be used to help assess the need for time critical removal actions, as well as to help identify the most appropriate analytical methods to screen for and analyze for asbestos. Details of the sampling approach can be found in the Quality Assurance Project Plan for Phase I (EPA 2000a).

Phase I sampling continued for several years, modified as necessary as new information was collected. Under Phase I, thousands of samples were collected. EPA sampled many areas at or near the former vermiculite mine, the former Screening Plant, the former Export Plant, several schools, public ball fields, and hundreds of residential and commercial properties. Measurable levels of asbestos were found in many of the locations. All media were affected, including air. This data, along with Phase II sampling and other information, was critical to EPA's initial decision to conduct emergency response time critical removal actions at several locations throughout Libby.

3.2.2 Phase II

Phase II sampling was designed to complement Phase I and was focused on a series of issues related to sampling and analysis of environmental samples suspected of containing asbestos. These issues included:

- What method(s) is(are) best for *collection* of air samples?
- What method(s) is(are) best for *analysis* of air samples?
- Are the levels of asbestos observed in Libby of potential human health concern?

Phase II was conducted in 2001. It was not intended to be a systematic or comprehensive study and hence did not span all possible exposure conditions or locations. The plan emphasized that the data should be interpreted only as providing an initial estimate of the range of exposures and health risks Libby residents may experience. The basic study design involved conducting a number of "scenarios" during which environmental media (dust, soil, vermiculite insulation) were disturbed by activities that residents or workers routinely conduct (normal activities in a home; aggressive cleaning within a home; working in vermiculite insulation; rototilling soil). Before, during, and after, the surrounding air was sampled to determine if asbestos was present. Only a limited number of locations were sampled, but the data clearly showed that measurable levels of asbestos were released to the air from various media during typical activities. EPA used this information, along with Phase I, to produce screening level risk estimates and to improve understanding of sampling and analysis approaches. Details of Phase II sampling and results can be found in the Phase II Quality Assurance Project Plan (EPA 2001a) and the Phase II Study Data Summary Report (EPA 2005a).

3.2.3 Cleanup-Related Sampling

Once emergency response removal actions began in 2000, a great deal of environmental sampling was necessary to support cleanup: soil and dust samples were needed to delineate areas of contamination; soil and air clearance samples were needed to ensure cleanups were complete; perimeter air samples were needed to ensure that no significant amount of asbestos was migrating from work areas; personal air samples were needed to monitor exposure to cleanup workers. This sampling continues today. Because of the wide-variety of sample types collected, plans for cleanup-related sampling are provided in numerous documents, including, but not limited to, (1) the Phase I QAPP (EPA 2000a), (2) the Pre-Design Inspection Work Plan (CDM 2003a), (3) the Response Action Work Plan (CDM 2003b), (4) various property specific work plans, and (5) various Health and Safety Plans. While this data was collected for very specific purposes at individual properties, taken as a whole it provides a great deal of information about the nature and extent of contamination at the Site.

3.2.4 Remedial Investigation

Once the Site was considered for listing on the NPL, planning began for conducting an RI/FS. The RI for OU4, as a sampling event, began in 2002. There have been several major components to the RI. Each is discussed below.

3.2.4.1 Contaminant Screening Study (CSS)

The CSS built upon the knowledge gained through Phase I and Phase II. Once the decision was made to expand the cleanup to residential and commercial properties across the entire Libby area in 2002, the CSS was designed as a comprehensive, site-wide screening program aimed at collecting readily available information through inspections, verbal interviews, and soil sampling. This information would be used, along with other information, to support decisions at individual properties. The objective was to classify all residential and commercial properties in the study area as either (1) requiring emergency response cleanup, (2) requiring more investigation before a decision could be made, or (3) likely requiring no further action. Coupled with Phase I, the CSS would provide substantial information about the nature and extent of contamination at the Site. The CSS emphasized identification of potential sources of Libby asbestos at specific properties, including, but not limited to, vermiculite insulation, contaminated soils, vermiculite in building products, or a history suggesting potential dust contamination (such as a former W.R. Grace worker living in the house).

During the CSS, EPA's contractors inspected and sampled approximately 3,700 properties in the Libby study area. The results of the CSS, along with other technical information, were used to select and prioritize residential and commercial properties for emergency response cleanup. Wide-scale cleanup of these properties began in late 2002 and continues today. Details of the CSS can be found in the Sampling and Analysis Plan, Contaminant Screening Study, Libby Asbestos Site (CDM 2002 and 2003c), Sampling and Analysis Plan, Remedial Investigation (CDM 2003d), and the Contaminant Screening Study Results Report (CDM 2005).

3.2.4.2 Performance Evaluation Study (PE Study)

Existing methods for analysis of asbestos in soil were largely developed specifically for testing commercial asbestos products or were modified from these methods. These commercial products generally contained "higher" concentrations of evenly distributed asbestos throughout relatively homogeneous samples. EPA noted early in our response at Libby that these methods may not be suitable for analyzing soil samples at Libby, where concentrations of concern for asbestos may be lower, the asbestos is not distributed uniformly, and the soils are complex. To help address this issue, EPA, with technical assistance from USGS and others, designed and implemented a PE Study aimed at evaluating existing and modified analytical methods for detecting and quantifying asbestos in soil. The PE Study was carried out in several stages from 2002 through 2005. The results of the study were used to develop an effective, cost efficient, site-specific soil analysis method that was used to analyze over 15,000 soil samples collected during the CSS. The study was also used to improve quality control for sample analysis and to evaluate the suitability of many soil analysis methods for use in Libby. Details of the PE Study can be found in the PE Study Data Summary Report (EPA 2005b) and are discussed more in Section 5.

3.2.4.3 Post-Cleanup Sampling

As EPA designed and implemented a time critical emergency response cleanup plan for residential and commercial properties, a number of uncertainties existed that could not be resolved immediately. Given these uncertainties, EPA decided early it was important to evaluate the technical efficacy of the cleanup plan as it progressed. To help accomplish this task, EPA designed and implemented a Post-Cleanup Sampling Plan as part of the RI (CDM 2003e). Post-cleanup sampling involved revisiting properties that had undergone cleanup and collecting numerous air and dust samples to measure residual or reintroduced asbestos levels. In addition to evaluating how successful the cleanups were over time, the results of post-cleanup sampling are being used to obtain actual exposure measurements (through collection of stationary air samples in homes and personal air samples affixed to residents) for use in assessing residual risks. The results of the first round of post cleanup sampling can be found in the Post Cleanup Sampling Technical Memorandum (CDM 2004). Additional post-cleanup sampling was conducted in 2005 as part of Supplemental RI Sampling and will continue in the future.

Comment [15]: The RI or FS should, somewhere, indicate whether this sampling and analysis indicated cleanups were successful.

3.2.4.4 Supplemental Remedial Investigation Sampling (RI Supp Sampling)

The most recent major RI sampling event was conducted in 2005. The goal of the RI Supp Sampling was to fill remaining, critical data gaps prior to completion of the BRA and preparation of this RI/FS Report. The emphasis was on lower level exposures and asbestos concentrations. This sampling involved numerous tasks including more focused post-cleanup sampling, detailed outdoor scenario sampling (similar to Phase II, but broader in scope), and reanalysis of existing samples to lower sensitivities. Details of the sampling and analysis can be found in the Supplemental Remedial Investigation Quality Assurance Project Plan for Libby, Montana (EPA 2005c).

Comment [16]: Do you mean higher sensitivity / resolution / precision that results in lower detection limits? Seems like lower sensitivity would mean less precision and higher detection limits.

3.3 Other Superfund Response Investigations

3.3.1 ATSDR

Concurrent with EPA investigations conducted in 2000 and 2001, ATSDR conducted several actions aimed at assessing impacts to public health from contamination in Libby. These actions included:

- Voluntary medical testing of current or former residents of Libby. This testing was conducted primarily over a period of two years, though the majority of participants were initially tested during 2000. Two important goals of the medical testing program were to identify asbestos-related health effects of participants exposed to Libby asbestos and to characterize exposure pathways that may have contributed to findings of disease. Testing included responding to a detailed questionnaire, performing lung function tests, and undergoing chest radiographs (X-rays). Over 7000 current and former residents of Libby and the surrounding area participated during 2000 and 2001. The results of this large-scale medical testing program showed that roughly 20% of the participants had pleural lung abnormalities, including many individuals who did not work at W.R. Grace or live with W.R. Grace workers (ATSDR 2001). Numerous potentially complete exposure pathways were identified, many of which still existed in 1999, some of which still exist today.
- CT Study. As a follow up to large-scale medical testing, ATSDR also conducted a smaller study that involved computed tomography (CT) testing of the chest. This study was focused on participants of the larger study whose chest X-rays were indeterminate. The study found that roughly 28% of those tested (98 of 353) showed lung abnormalities that were not conclusively identified during X-ray testing (ATSDR 2002). Roughly 30% of these individuals were not former W.R. Grace workers or their household contacts.
- Mortality Study. ATSDR reviewed death certificates from the period 1979-1998 to develop accurate information about deaths potentially associated with asbestos exposure in Libby. This study found that rates of asbestos related deaths among residents of Libby were significantly higher than State and National averages (ATSDR 2002a).

All of these studies supported EPA's decision that emergency response time-critical removal actions were necessary to protect public health in Libby.

3.3.2 USGS

The USGS has performed several technical investigations aimed primarily at characterizing the mineralogy and other physical aspects of Libby asbestos. Using state of the art analysis techniques on samples obtained at various locations at the former vermiculite mine, USGS showed conclusively that the materials were asbestiform in nature, consisted of a unique and wide range of mineral types that were related to the more commonly known tremolite asbestos, and consisted of a range of morphologies (e.g. size and shape) ranging from blocky crystals to long, thin fibers. USGS also concluded that their findings underscore the fact that traditional morphological definitions of asbestos used commonly in the regulatory community may not adequately define amphibole mineral fiber from either a toxicological or regulatory perspective (Meeker 2003). EPA used this information to develop a definition of the asbestos attributable to the Libby vermiculite deposit (called Libby asbestos) and to refine analytical techniques in air, dust, and soil.

3.4 Other Relevant Investigations

The discussions below summarize investigations from areas outside of Libby that have direct relevance to the Libby RI/FS. Each is discussed in more detail or cited later in the report.

3.4.1 Versar and Region 10 Studies

The presence of asbestos in vermiculite was a concern well before EPA began emergency response actions in Libby in 2000. In 1985, EPA began evaluating exposures to asbestos to products containing vermiculite. In 2000, EPA Region 10 initiated a study of horticultural products containing vermiculite. In 2001, Versar conducted a follow up to both studies, focusing on an exposure assessment for vermiculite insulation. The recent studies showed that vermiculite products can release significant concentrations of Libby asbestos to air when disturbed (EPA 2000b) (Versar 2003). This and other information resulted in national warnings by EPA, ATSDR, and NIOSH (the National Institute for Occupational Safety and Health) concerning the hazardous nature of vermiculite insulation.

3.4.2 Libby "Sister Sites"

W.R. Grace shipped vermiculite from Libby nationally to a reported 200+ sites for processing and resale. A number of these sites are being evaluated by EPA and ATSDR. The amount of information collected at these facilities is too large to reproduce or even discuss in this report. However, it is critical to note that EPA and other agencies are taking aggressive actions to protect public health at many of these sites. Of note are investigations and cleanup conducted by EPA at the Former Intermountain Insulation Facility in Salt Lake City, Utah and the Western Minerals Plant in Minneapolis, Minnesota.

3.4.3 Marysville, Ohio – OM Scott Studies

Researchers funded by ATSDR recently completed a follow up to a prior medical study of workers exposed to Libby vermiculite at the OM Scott & Sons lawn care products plant in Marysville, Ohio. The studies found that the number of workers with lung abnormalities increased from approximately 2% in 1980, when the plant ceased using vermiculite from Libby, to approximately 26% today. The original Lockey study was among the first to attribute lung abnormalities to exposure to vermiculite (Lockey 1981).

3.4.4 El Dorado County, California

EPA Region 9 is currently working in areas of California to address concerns about potential effects of asbestos found naturally in local soils. While regulatory agencies have been aware of a potential problem in the area for some time, recent discovery of asbestos in a school in El Dorado County has prompted cleanups, additional investigations, and public advisories. Investigations continue and Region 9 is working with other technical experts to determine appropriate follow up actions. Region 9 has conducted extensive sampling documenting the release of asbestos fibers to air when contaminated soil is disturbed.

3.4.5 World Trade Center (WTC)

After the September 11, 2001 terrorist attacks, EPA Region 2 and other agencies have conducted extensive monitoring and cleanup programs in the surrounding areas, primarily to address dust that was released during the collapse. While this work is intended to address several contaminants of potential concern (COPCs), asbestos is a primary focus. EPA and other partners have conducted investigations that are relevant to efforts in Libby:

- A *Contaminants of Potential Concern Report* was produced that established health-based benchmarks to support dust cleanup in areas surrounding the former WTC.
- A *Background Study* was conducted to determine asbestos and other COPC levels in air and indoor dust from areas believed to be unaffected by the WTC collapse.
- A *Confirmation Cleaning Building Study* was conducted to evaluate the effectiveness of various cleaning approaches used for WTC dust.

Add other off-site studies as appropriate.

4.0 Physical and Chemical Description of Libby Amphibole (LA)

The vermiculite deposit near Libby is contaminated with a form of amphibole asbestos that is comprised of a range of mineral types and morphologies. This form of amphibole asbestos has been termed by EPA as Libby amphibole or Libby asbestos (LA). LA is the primary contaminant of concern at the Libby Asbestos Site. This section describes the physical and chemical characteristics of LA, with emphasis on characteristics that are important for measurement of LA in environmental samples and assessment of health risks.

Comment [17]: See later comment – seems like Libby asbestos would be a subset of Libby Amphibole, as not all amphoboles are asbestos.

Nomenclature is very important when discussing asbestos. Asbestos and many of its attributes have been defined differently over the years. There are mineralogical definitions, regulatory definitions, toxicological definitions, analytical definitions, and commercial definitions. In many cases these overlap, but in many cases they do not. These definitions and rationale provide for significant debate and controversy and are sometimes used inappropriately. For instance, a regulatory or commercial definition is not suitable for toxicological purposes. For Superfund response actions in Libby, EPA has considered all the relevant definitions and underlying rationale, and made an informed, weight-of-evidence decision about which materials are of concern at Libby (e.g. are considered CERCLA hazardous substances), how they should be measured, and how they should be discussed. The term Libby amphibole refers *generally* to amphibole materials that originated in the Libby vermiculite deposit, have the ability to form durable, long, and thin structures that are generally respirable, and can reasonably be expected to cause disease.

4.1 Asbestos in General

The term "asbestos" is of commercial origin and refers to a group of naturally occurring fibrous silicate minerals with the propensity to form strong, thin fibers. Asbestos fibers are extremely small, on the order of microns. One micron is 0.001 millimeters, which is about 1/100th the diameter of a human hair.

There are two basic categories of asbestos, serpentine asbestos and amphibole asbestos. Asbestos is formed by hydrothermal alterations associated with igneous and metamorphic rocks, typically along veins and fractures. The term "asbestiform" is generally applied to minerals that exhibit the basic characteristics of asbestos – again, the propensity to form durable, long, thin fibers.

Comment [i8]: Here's where I start getting confused. If an amphibole has asbestiform qualities, does that make it asbestos?

Serpentine asbestos is found exclusively in a form called chrysotile. The term "serpentine" is not unique to asbestos, but refers to a larger family of minerals with cylindrical or tubular structure. Chrysotile is the only serpentine mineral with asbestiform qualities. Chrysotile, known as white asbestos, is the most widely distributed and commercially valuable asbestos mineral. It is mined throughout the world and used in a variety of commercial applications. It has a layered structure made up of two different types of layers. The crystallographic mismatch between those two types of layers is responsible for a curvature in the structure that results in the characteristic cylindrical or tubular form of the chrysotile fibers (Figure 4-1). The connections between the layers are weak, giving the chrysotile asbestos fibers great flexibility. The combination of flexibility, chemical inertness, high tensile strength, and resistance to high temperatures has made chrysotile (and some amphiboles) a preferred ingredient for fireproofing materials, abrasive materials, and insulating materials. Of note, chrysotile fibers are seldom found in a pure form, but are nearly always contaminated with some form of amphibole asbestos (citation). I've read this in a few places, but can't recall exactly where.

Amphibole asbestos, on the other hand, has different varieties that have the same basic structure but different mineral compositions. The term "amphibole" is not exclusive to asbestos, but rather refers to a larger family of silicate minerals forming prismatic or needlelike crystals that generally contain iron, magnesium, calcium and aluminum in varying amounts, along with water. Amphiboles include non-asbestiform minerals like hornblende and jade but also include various forms of minerals with asbestiform qualities. Amphibole fibers are solid and are less flexible than chrysotile fibers, and they tend to split into small, straight, sharp splinters (Figure 4-1). The most well known types of amphibole asbestos include crocidolite, anthophylite, amosite, tremolite, and actinolite. Crocidolite and amosite, known as blue and brown asbestos, were and are mined substantially and used commercially for the same uses as chrysotile.

Asbestos, *especially* chrysotile asbestos, is found throughout the world. Its widespread commercial use in products such as pipe wrap, ceiling tiles, floor tiles, fireproofing, brake pads, insulation, and other construction materials make it ubiquitous in modern society. While trying to fully quantify "background" exposures is beyond the scope of this report, it is safe to say that a large percentage of residents of the U.S. are exposed to significant amounts of asbestos throughout their lives. Asbestos is present in many construction and other materials that are frequently disturbed or deteriorating; it is likely present in surface dusts of many buildings containing asbestos materials or located near other sources; it is present in "background" air and dust of metropolitan areas (EPA 2003a; other citations regarding background?) and there are naturally occurring deposits of asbestos throughout the U.S. Vermiculite products from Libby (especially vermiculite insulation and vermiculite lawn care products) were used in millions of homes and yards across the nation. While many countries have completely banned all new production and import of asbestos, others, including the U.S., have not.

4.2 Geology of Libby Vermiculite

Vermiculite is a general term applied to a group of platy, hydrated silicate minerals. Most vermiculite minerals are the product of aqueous alteration (or weathering), by ground water, of micas such as biotite. Vermiculites encompass a wide range of chemical compositions, vary in color from light yellow to green to brown to black, and generally have a bronze hue (Van Gosen 2002). The distinctive feature of vermiculite is its ability to expand, accordion-like, when heated as the water included in the mineral matrix turns to steam. Individual particles can expand from six to as much as thirty times their original volume.

The mountain containing the vermiculite deposit at Libby is comprised of a variety of minerals. The amount or percentage of vermiculite in the deposit varies greatly, from approximately 30% to approximately 85%. In certain veins and specific mineral areas, amphibole minerals formed hydrothermally, forming intergrowths within the vermiculite. The amount or percentage of amphiboles also varies considerably, but can be as high as 75% in veins running through the deposit (Pardee and Larsen 1928).

4.3 Chemistry of Amphiboles from the Libby Vermiculite Deposit

Beginning in 2000, the USGS conducted extensive testing of amphibole material samples obtained from various locations at the former vermiculite mine. A total of thirty locations from the mine were sampled with attempts made to capture the full range of variability in texture and composition. They used a combination of three analytical techniques to characterize composition, mineralogy, and morphology of the materials. X-ray diffraction (XRD) was used to determine and confirm the presence of amphiboles. Electron probe microanalysis using wavelength dispersive spectroscopy (EPMA/WDS) was used to determine the exact compositions of the amphiboles. Scanning electron microscopy combined with energy dispersive X-ray analysis (SEM/EDS) was used to characterize the morphology and to determine the mineral composition among individual small particles. The combination of three methods was necessary to conduct a conclusive analysis of the material.

The results of this analysis showed that the several amphiboles existed and differ only slightly in composition. Using a mineralogical classification system (Leake 1997), USGS identified six primary amphibole species (Figure 4-2): edenite, richterite, magnesio-arfvedsonite, tremolite, winchite, and magnesio-riebeckite. The dominant species was winchite, with a lesser amount of richterite, then lesser amounts of other species. Other studies (Gunter 2003; Wylie and Verkouteren 2000) had similar and consistent results. All of these species, with the exception of magnesio-arfvedsonite, present characteristics of fibrous amphibole asbestos. All are closely related to the more commonly known, and Occupational Safety and Health Administration (OSHA) regulated, tremolite-actinolite series of amphibole asbestos (Meeker 2003). Again, this series of closely related amphibole species originating from the Libby vermiculite deposit have been titled by EPA as Libby amphibole.

Comment [l9]: This list includes asbestos (tremolite, listed above when you further defined amphiboles that are asbestos) and other amphiboles that have asbestiform qualities but that you did not list above as asbestos. . . I'm getting confused . . are all asbestiform amphiboles also asbestos? What are we concerned about in Libby: asbestos, or amphiboles that are asbestiform – or is this a distinction with out a difference?

What's confusing is that I'm searching for a clear definition of whatever it is that poses risk in Libby.

Comment [l10]: Which, I conclude, should include both asbestos and asbestiform amphiboles.

For ongoing mineralogical and chemical verification of LA during sample analysis, and to differentiate LA from other amphiboles or materials that may be present, EPA's laboratories use EDS to verify the mineral composition. LA is characterized by the presence of sodium, magnesium, potassium, calcium and iron. It should be noted that the chemistry of LA is not absolute; the chemistry of even individual LA structures may vary. EPA's labs use a range of EDS spectra associated with the amphibole species above to identify structures as LA (SRC 2005).

4.4 Physical Characteristics of Amphiboles from the Libby Vermiculite Deposit

There has been considerable debate in the scientific and regulatory communities regarding the origin of fibers or structures and how important this is to their toxicity. Specifically, distinct long, thin structures can be created independently during formation of the minerals, or they can be created later by the mechanical breaking, or cleaving, of larger crystalline structures. The former is often denoted as a "fiber" and the latter is often called a "cleavage fragment" or an "acicular cleavage fragment." "Fibers" are generally flexible, whereas "cleavage fragments" are not.

Some scientists have argued that cleavage fragments are not relevant toxicologically and should not be treated the same as a fiber. Indeed, OSHA specifically excluded cleavage fragments from occupational regulation in 1992, though even in this decision noted that the weight of evidence suggests that cleavage fragments could possess carcinogenic qualities (Weis 2002). A large number of scientists believe that if cleavage fragments display the same general characteristics thought to make distinct fibers harmful (e.g. made of the same minerals; same long, thin structure), they should not be treated significantly different. Numerous studies have shown that materials traditionally considered *not* to be asbestos have carcinogenic properties similar to those that are (Weis 2002).

In practice, it is often difficult to differentiate fibers from cleavage fragments. The amphiboles originating from the Libby vermiculite deposit display characteristics that range from blocky crystals, to acicular, non-flexible cleavage fragments, to long, flexible fiber bundles (Meeker 2003). USGS found the material, as a whole, to be highly friable. Even gentle disturbance of what appears to be a solid, coherent rock can liberate very large numbers of particles that are long and thin (Meeker 2003).

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After analyzing thousands of air and dust samples collected in various locations around Libby, EPA's laboratories reported that "cleavage fragments" represented only 1-5% of all Libby amphibole particles observed (EMSL 2002). Similarly, the vast majority of all particles observed in air and dust samples were simple, individual particles and were not clustered, bundled, or grouped (EMSL 2005, other lab reports). This makes detection and quantification considerably more simple and accurate than if the particles were grouped in complex matrices.

Comment [l11]: This leads me to believe that cleavage fragments are not important in Libby....

Considering the scientific discussion on the potential risks posed by cleavage fragments, the analytical challenges associated with identifying cleavage fragments, the demonstrated ability of LA crystals to cleave into easily observable long, thin particles, and the magnitude of the health effects observed in Libby, EPA has made a weight of evidence decision to *not* exclude cleavage fragments or larger blocky crystals from the universe of potential asbestos particles of concern at Libby. A detailed discussion of the issues associated with cleavage fragments, including

Comment [l12]: . . . but then I see here that you do include them. I'd place less emphasis on the preceding paragraph.

specific details related to Libby amphibole, can be found in a memorandum from Dr. Chris Weis to Paul Peronard entitled "Review of R.J. Lee Discussion of Cleavage Fragments (Weis 2002).

For the remainder of this report, the terms "fiber," "structure," and "particle" will be used interchangeably to denote any measurable particle of LA, including cleavage fragments, that is asbestiform in nature and falls within the general "counting rules" of a particular analytical method. Similarly, in certain analytical results, the terms structure and fiber are used interchangeably and have no special connotation.

Comment [I13]: Is this the definition I've sought: if it's asbestiform in nature, we're interested?

4.5 Particle Size Distribution of Libby Amphibole

One important consideration about which particles may be of health concern is respirability. A respirable particle is usually considered a particle that can be breathed into the deep lung. Generally this is a particle that is less than 10 microns in effective diameter. The particles of most concern have a propensity to make it past the upper respiratory system and are not effectively discharged by the body.

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Beyond basic size, the relative shape of asbestos particles seems to be an important consideration in determining their toxicity. Whether an individual particle formed as a discrete fiber or as a cleavage fragment, it is becoming more accepted that long, thin particles seem to be substantially more carcinogenic than short, stubby ones. This issue is discussed in more detail in Section _______ of the RI Report as well as the BRA. This apparent correlation between fiber size and shape and toxicity makes determination of a *particle size distribution* a critical consideration for assessing risks from asbestos.

Particle size distribution refers to the unique array of particle sizes and shapes attributable to a particular source of asbestos in a given situation. The particle size distribution is influenced by the chemical and physical nature of the asbestos as well as the mechanical forces that have acted on the material. To determine the particle size distribution in a given situation accurately, one must observe and record the sizes of many, many particles. The more particles observed, the more accurately one can depict the particle size distribution of the asbestos, and the more accurately one may be able to estimate potential health risks.

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At the Libby Asbestos Site, because so many samples have been analyzed, EPA has produced an accurate representation of the sizes and shapes of LA particles that are found in the Libby environment. Individual samples or locations may vary according to the unique situation present, but overall, the particle size distribution has been found to be reasonably consistent across the Libby site. Put a different way, the distribution of particle sizes found in a particular media in one location, taken as a whole, are expected to be reasonably similar to distribution of particle sizes found in that media at other locations. This is expected to be true over time as well. Indeed, Libby amphibole samples associated with vermiculite processing operations analyzed by W.R. Grace in the 1970s showed a very similar particle size distribution to those collected by EPA in various residential and commercial locations around Libby in 2001 and 2002 (Weis 2002).

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Comment [I14]: This seems like a very fundamental and important hypothesis. To make it compelling I suggest you first describe what we've observed in studies and at the site. Then explain why we expect to see this behavior in general across the site.

Using the particle size distribution generated for Libby allows EPA to more accurately interpret sample results. If EPA observes a small number of particles in a particular sample, the particle size distribution can be then be used to accurately estimate how many particles of other sizes are actually present in the environment where that sample was taken. This has extremely important ramifications for risk assessment and sample analysis that are discussed in detail in Section _______ and the BRA.

A graphical depiction of Libby particle size distributions for air, dust, and soil samples is shown in Figure 4-3. As seen, the majority of LA particles in all media are between 1 and 10 microns in length and between 0.1 and 1 micron in width. Particle size distributions observed in soil and dust samples are similar, with fibers observed in air samples generally being slightly longer. This indicates that longer particles seem to be preferentially released from dust and soil into the air. The typical aspect ratio, which measures the ratio of particle length to width, is larger than 10 to 1. Need to add more about how Libby's distribution compares to other locations, if available. Are we enriched in long fibers?

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Comment [115]: Same comment – explain how you know this.

Comment [116]: Perhaps a distinction with out a difference, but it seems that the difference in air sample distribution could be a result of preferential suspension in air of longer particles, and not necessarily preferential release.

Comment [117]: The ranges of 1-10 micron lengths and 0.1 – 1.0 width yields aspect ration equal to 10 to 1, not larger than.

Comment [118]: Simply put, does LA morphology simply tend toward long thin fibers?

4.6 Behavior of Libby Amphibole in Air

Left undisturbed, asbestos-containing materials (e.g. bulk materials, soil, or surface dust) do not present a health risk. However, once disturbed, those sources can release asbestos into the air where it can be breathed.

Unlike gases that stay airborne indefinitely, asbestos is a solid material and will tend to settle to the ground. Once airborne, a number of factors influence how long an asbestos particle will remain in the air. The most important factor is the thickness of the particle, with other factors such as length and static charge being somewhat less important (EPA 2003b). Most LA particles observed in air in Libby have a thickness in the range of 0.1 to1 microns, with an average of around 0.5 microns. In air that is moving, asbestos particles of around 0.5 microns in thickness will typically fall out of the air and be re-deposited on surfaces with a "half time" of about 2 hours. The half time is a measure of how long it takes for the concentration of a material to decrease by 50%. For example, if the starting concentration were 0.001 s/cc, and the half time were 2 hours, after 2 hours the concentration would be 0.0005 s/cc, after 4 hours the concentration would be 0.00025 s/cc, etc. Particles at the low end of the thickness range (closer to 0.1 microns) may remain suspended for significantly longer (half-time of about 40 hours), while fibers at the high end of the thickness range (closer to 1 micron) will tend to fall out more quickly (half time of about ½ hour) (Baron 2004). These calculated estimates of residence time in air are generally consistent with observations from field studies of asbestos residence time in air. For example, the W.R. Grace Company (Grace 1976) performed "drop tests" to see how much asbestos was in air at varying times after dropping some vermiculite on the ground. The results indicated that concentrations in air rose for about 5-10 minutes (this increase was probably due to the mixing effect), and then fell with a half time of about 30 minutes. In another case, Versar (2003) performed a series of studies for the USEPA in which vermiculite insulation in attics was disturbed and asbestos concentrations in air were measured over time. Based on their data, Versar concluded that most asbestos fibers settle from attic air within about 24 hours.

Comment [119]: Picky -- but can you qualify? Gently mixing, typical indoor air movement, etc.

As long as an LA particle remains in air, it will tend to move in the same way that the air moves. This means that concentrations of LA will initially be highest at the point where the disturbance occurred, but will tend to decrease after time as the particles are moved about by air currents. In indoor air, the time that it takes for LA particles to mix in the air of a room depends on how much airflow there is, but mixing would usually be expected within about 5-30 minutes (Nazaroff 2005). When a release occurs in outdoor air, the degree of mixing and transport will depend mainly on wind speed. If the air is completely calm, the concentration might remain elevated near the source for several hours. If the wind is blowing, the particles will tend to be rapidly dispersed away from the source of release.

These complex behaviors (re-suspension, fallout, dispersal) of LA particles in air are important in selecting strategies for making, and interpreting, measurements of airborne LA. This is discussed more in Section 5.1.1.

5.0 Sampling and Analysis of Libby Amphibole

I expect we will add detail to Section 5 as the team deems appropriate, but it is only intended to provide the reader a basic understanding, not to provide extensive detail on every aspect of sampling & analysis.

Comment [i20]: With his intent in mind I would change the intro to do three things only. First, lay out the SCM as noted in the comment below. Second, explain what you need data for: to refine the SCM, to assess the level of risk, to find the level and extent of contamination, and to determine that a response action successfully achieved cleanup. Third, explain, as you do in the third paragraph, the situation with analytical techniques.

As noted in Section 4, asbestos particles in air cause the most concern because they can be breathed. Therefore, measurement of asbestos concentrations in air is critical to assessing the magnitude of exposures and consequent health risks. However, if one wishes to find the source of the problem, it is also important to measure asbestos in other media. From where did the asbestos in the air come? From soil? From dust? From some other source? How much asbestos in those media is necessary to cause problems?

In Libby, based on a conceptual model of how the contamination spreads (discussed in later in Section 6) EPA developed a sampling and analysis strategy designed to answer several types of questions: How much LA are residents and workers exposed to (or would they be exposed to) in different situations? How much LA is present in different source materials? Where are those source materials located? What happens when you disturb those sources? Is LA migrating away from cleanup sites? Were cleanup standards achieved?

Comment [i21]: Jim, I think it would be best for the reader to have in mind the site conceptual when reading this section, as that would provide the logic that drives how you sampled. Two suggestions: you could put the SCM before this section, or you could briefly summarize the SCM in the intro to this section (would would end up being redundant).

Unfortunately, asbestos is very difficult and expensive to measure at low concentrations. Many existing analytical methods, especially for soil, are outdated or ineffective. Most analytical methods are complicated and highly technical, and different analytical methods are needed for different media. Consequently, there is no single sampling approach or analytical method that will answer every question. Because of this, EPA has used a variety of sampling and analytical methods in Libby, each method selected for a specific purpose based on what the method was designed for, its effectiveness, its implementability, and its cost. The sampling strategy has evolved over time. EPA's emergency response cleanup plan and associated sampling strategy were built to minimize the limitations and uncertainties associated with asbestos sampling and analysis to ensure the cleanups were protective, implementable, and cost effective. The RI sampling strategy was built to provide the information needed to make protective emergency response and remedial action decisions while attempting to fill as many data gaps as possible.

This section provides a very *basic* overview of different sampling and analysis techniques available for asbestos, which of those techniques have been used in Libby, and a discussion of the Quality Assurance/Quality Control (QA/QC) program EPA employs to ensure that the data we collected is of sound quality. For the sake of brevity, and due to the complexity and number of samples collected at Libby, this report does not provide detailed information about all sampling events or programs. Those details are provided in the various sampling and analysis plans, standard operating procedures, and analytical methods discussed and cited throughout the report and available in the Administrative Record for the Site. Table 5-1, at the end of the Section 5.3, presents a *summary* of sample collection and analysis methods used at Libby. Those seeking more detail regarding specific methods should consult the applicable Sampling Analysis Plan, Quality Assurance Project Plan, or method SOP.

5.1 Air and Dust Sampling and Analysis

The methods for air and dust sampling and analysis are far more established than those for soils and other bulk materials such as vermiculite insulation. Especially for air, there are approved, standardized analytical methods that are generally considered acceptable and capable of detecting what are generally considered low amounts of asbestos.

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5.1.1 Air Sample Collection

At the most basic level, air sampling for asbestos involves pumping air through a filter designed to let air pass through but capture asbestos particles. If one knows how much air was pumped through the filter (liters or cubic meters of air), then counts how many asbestos particles are present on the filter (number of particles), one can calculate how many asbestos particles were present in the air (number of particles per liter of air). In practice it is far more complicated, but the basic premise remains the same.

No matter the method used for collecting samples, it is critical that samples be collected during the *activity* (or a simulation of the activity) that may disturb the potential asbestos sources. Just like one wouldn't sample air from a smokestack when the smokestack is not operating, it is of little use to sample a vacant room or area with no disturbance of the dust, soil, or other materials that contain asbestos. As discussed in Section 4, particles of LA in dust or soil become suspended in air readily, but can disperse rapidly and do not stay suspended indefinitely. For this reason, except in very limited circumstances, EPA does not conduct any stationary air sampling in Libby when there is no activity, or simulated activity, that could disturb materials containing asbestos.

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There are two basic ways to collect air samples.

5.1.1.1 Stationary Monitors

Stationary monitors consist of an air pump that pumps air through a filter for a certain period of time in one location. Because no one is carrying them and they are easy to maintain, stationary monitors are relatively inexpensive and easy to use. They are valuable for measuring asbestos concentrations in a specific location (e.g. at the perimeter of a cleanup). With stationary monitors, it is usually easier to sample very large volumes of air, making them sensitive to low concentrations.

However, as discussed in Section 4.6, when measuring LA particles that emanate from disturbance of a localized source, stationary monitors have limitations. For instance, LA that is suspended by an activity such as a person raking soil may disperse or settle to the ground before it reaches a stationary monitor located some distance away. In other words, the air around a stationary monitor away from a localized disturbance is likely to be cleaner than the air near the disturbance. One using the stationary monitor to measure asbestos air concentrations a person was exposed to might underestimate the actual values. Sampling at Libby and other locations has consistently shown this to be the case (EPA 2005a; Ecology & Environment 2005)

These drawbacks can be partially overcome through various means. First, the stationary monitor can be set up nearer the activity or disturbance. Or, if the disturbance is widespread or there are multiple disturbances, the monitor can be set up within the area of disturbance. Second, multiple monitors can be used. Lastly, one can conduct *aggressive* sampling with stationary monitors. Aggressive sampling usually involves blowing down the area of interest (e.g. usually an indoor room or attic) with a leaf blower and then running fans to ensure the air continues to circulate while the stationary monitors pump air. The intent is to ensure that any asbestos lying around in dust that *could* be later disturbed is suspended and captured in the air filters.

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Understanding these benefits and drawbacks, EPA has employed stationary monitors for a variety of applications in Libby, including:

- Aggressive clearance sampling in attics and interior living spaces to ensure cleanup criteria were met. In this case, several stationary monitors are used.
- Air sampling in homes that have already undergone cleanup and achieved clearance criteria. Several stationary monitors around the home are used while residents conduct normal activities.
- Perimeter monitoring around active cleanups to ensure asbestos is not migrating from the work site to surrounding areas. Monitors are either placed in several locations around the cleanup or in the primary wind direction.
- Monitoring of ambient air around Libby.

5.1.1.2 Personal Monitors

Personal monitors are portable air sampling pumps and filters that are usually worn by people. Personal monitors are valuable for measuring air concentrations individuals are actually exposed to, even if they are moving from place to place. Because they must be worn, are slightly cumbersome, and require significantly more maintenance, they are not as easy or inexpensive to use as stationary monitors. And because the pump is usually smaller, they often sample smaller volumes of air, making them less sensitive to lower concentrations in air than stationary monitors.

EPA has employed personal monitors for two primary applications in Libby:

- Evaluating exposures to workers conducting cleanup.
- Measuring exposures to individual persons disturbing localized asbestos source materials. This can be during test scenarios designed by EPA to model specific conditions or during "real-life" activities by residents or others.

5.1.2 Dust Sample Collection

Dust can become contaminated with asbestos or other materials. This is especially important indoors, where dust can be easily disturbed through normal activities and suspended in the air. Most people spend a very large portion of their time indoors, so even low concentrations of asbestos in dust might cause significant exposures over time.

One way to determine if dust is contaminated is to disturb the dust and sample the air, as described in Section 5.1.1. However, this may not be feasible at all times, and one may simply wish to sample the dust itself to determine if it contains asbestos. There are two established approaches for sampling dust.

5.1.2.1 Wipe Samples

Wipe samples, in simple terms, involve taking a small "patch" designed to capture particles and physically wiping an area of interest. For asbestos, one wipes a specific area and then measures the amount of asbestos on the wipe. If one knows the amount of surface area that was wiped (square centimeters) and the number of asbestos particles on the wipe, one can calculate the number of asbestos particles in the surface dust (particles per square centimeter). Because they aggressively scour a surface, wipe samples are good for capturing the majority of particles on a surface, even those that are not likely to be re-suspended through normal activity.

EPA has not used wipe samples in Libby.

Comment [122]: Should you explain why not?

5.1.2.2 Micro-vacuum (Microvac) Samples

Microvac samples operate on the same principle as air samples – air is drawn through a filter designed to capture asbestos and dust. When collecting microvac samples, a small vacuum, or pump, is used to gently vacuum the dust from a surface. If one knows the surface area that was vacuumed (square centimeters) and then counts the number of asbestos particles on the filter, one can calculate the number of asbestos particles in the surface dust (particles per square centimeter). Microvac samples usually only pick up a fraction of the particles of a wipe sample, but one can assume those are the particles that are most likely to be re-suspended into the air in the future.

In Libby, EPA has used microvac methods in Libby to collect all indoor dust samples. This decision was based primarily on the assumption that microvac samples more accurately measure *releasable* fibers than wipe samples. However, to ensure we capture "worst-case" areas of contamination, samples are generally collected both in high traffic areas (where asbestos might be frequently tracked in) and in areas where dust would tend to settle out with minimal disturbance (window sills, tops of appliances). Dust samples are collected for two primary purposes:

- To help determine which properties, and which floors of those properties, require interior cleanup.
- To measure residual dust contamination at homes that have already undergone cleanup and achieved cleanup clearance criteria.

5.1.3 Air and Dust Sample Analysis Technologies

Once air samples and microvac dust samples are collected, they are analyzed in much the same fashion. The filters (or other preparations from the filter) are visually inspected under a microscope and the number of asbestos particles is recorded. The biggest difference between air and dust samples is how the filters are generally prepared for inspection under the microscope. Dust samples typically contain more material that tends to clog the filter and make asbestos particles harder to see under the microscope. This can also be true with air samples in dusty environments. For these types of samples, an *indirect prep* may be used. Indirect prep involves various steps aimed at minimizing or removing the surrounding materials (dust) that obscure the asbestos, then re-depositing the asbestos on a different surface for analysis under the microscope. Indirect prep enables samples to be analyzed that otherwise could not be, but it has some potential disadvantages. For instance, the methods used in indirect prep can break up complex structures, changing their size and shape and increasing the number of particles counted. As discussed in Section 4, the size and shape of particles are important to their toxicity. Results from samples analyzed with indirect prep must be interpreted with this in mind. For Libby air and dust samples, this effect is minimal due to the very small amount of complex structures observed to be present in Libby samples (need reference). Do we have any more information we could or should present on indirect prep here?

Beyond preparation, there are two commonly available technologies for analysis of air samples, one of which is applicable to dust samples as well.

5.1.3.1Phase Contrast Microscopy (PCM)

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PCM is relatively simple technology that is suitable only for analyzing air samples. PCM involves use of a small microscope with an approximate magnification of approximately 450x used to observe and count asbestos particles. Results are generally reported as structures per cubic centimeter of air (s/cc). PCM is an older technology and has two critical limitations. First, due to its limited magnification, it is unable to distinguish asbestos particles smaller than about 5 microns in length and about 0.25 microns in diameter. Second, there is no way to distinguish asbestos particles from other particles. However, PCM is easy to perform, is very inexpensive, and it is still required by OSHA for worker safety sampling. The predominant method used is NIOSH 7400.

In Libby, EPA uses PCM for analyzing personal air samples collected on cleanup workers. This is because (1) OSHA requires it, (2) the analysis can be performed quickly and inexpensively and (3) the intention of the samples is to screen for the presence of high levels of asbestos that would be of immediate concern even to workers wearing protective respirators. For such screening, complete accuracy is not necessary, but quick turnaround is, so any problems can be quickly identified and fixed.

5.1.3.2Transmission Electron Microscopy (TEM)

TEM is a more complex technology for analyzing air and dust samples (though it can be used for other media as well). TEM involves the use of a large, powerful electron microscope that can magnify by up to 10,000x to 20,000x to observe and count asbestos particles. There are numerous standardized TEM methods available. Results are generally reported in units of s/cc for air or structures per square centimeter for dust (s/cm^2). TEM is considered state of the art for air and dust sample analysis. Compared to PCM, TEM has two distinct advantages. First, it can see the smallest particles of concern, even those as small as 0.5 microns in length. Second, coupled with the use of energy dispersive X-ray analysis (EDS), TEM can distinguish between asbestos and non-asbestos particles and determine mineralogy. However, there are limitations with TEM. The analysis takes longer and is considerably more expensive than PCM, especially when looking for very low concentrations of asbestos.

Because of its proven effectiveness, various TEM methods are used to analyze most air and all dust samples in Libby.

5.1.4 Asbestos Particle Counting Rules

Once an air or dust sample is collected and is ready for inspection under a microscope, the analyst must have a set of rules for determining which particles are recorded, or counted, as an asbestos particle of concern. These are often referred to as *counting rules*. Each standardized analytical method usually has its own unique counting rules. However, there are numerous analytical techniques, and what constitutes a particle of concern remains a matter of debate. As a consequence, there are several counting rules available. Counting rules are complex and it is beyond the scope of this report to discuss the details of each method. However, the basics of several important counting rules are presented in Table 5-2.

Of the counting rules presented in Table 5-2, The ISO 10312 TEM Method counting rules are generally considered the most "inclusive" of all methods, meaning a wider range of particle sizes are recorded. It also provides the most information and detail about the particles observed. However, the ISO 10312 method is also expensive to perform.

In Libby, EPA has used ISO 10312 for a large number of air and dust samples. The large number of ISO 10312 and other TEM results from samples throughout Libby has allowed EPA to develop the detailed particle size distribution discussed in Section 4. The mathematical relationships derived from the particle size distribution allow EPA to convert results among counting rules. This allows the use of more economical analysis methods, such as the AHERA Method, while still ensuring that all particle sizes are accounted for. Again, this is discussed more in Section _____ and the BRA.

5.1.5 Sensitivities

Comment [123]: This section is excellent. You treat a technically and politically difficult issue very directly and effectively.

A detailed discussion of sensitivities, method detection limits, and other analytical terms is complex and will not be presented in this report. However, for many of the results presented and discussed later in the report, a basic understanding of sensitivity is critical for interpreting the data.

Sensitivity is defined roughly as the lowest concentration of asbestos that can be reliably detected *in a given sample*. If the sensitivity in a particular sample analysis was calculated as 0.001 s/cc, it means that:

- If the amount of asbestos in the sample is greater than or equal to 0.001 s/cc, it is highly likely to be detected.
- If the amount of asbestos in the sample is less than 0.001 s/cc, the analysis may miss it.

- If no asbestos was observed in the sample, it does not guarantee that there is no asbestos present. However, if asbestos is present, it is highly likely that it is present only at a level below 0.001 s/cc. When no asbestos is observed in a sample analysis, the result is usually reported as either a non-detect (ND) or denoted as a result lower than the sensitivity (<0.001 s/cc).

The sensitivity achieved in a particular sample analysis is flexible within certain limitations. For asbestos analysis of air and dust samples, sensitivity is a function of several variables, and there are three significant variables that are readily controlled:

- The analytical method used. Each analytical method, based on its specific attributes, has a theoretical lower limit of what it can detect and quantify.
- The amount of air that is pumped through the filter in a given sample. The more air, the higher the likelihood of detecting lower concentrations.
- How much of the sample is "inspected' by the analyst. The more of the sample that is inspected, the higher the likelihood of seeing and accurately estimating low concentrations.

For asbestos analysis, one generally seeks to (1) maximize the amount of air sampled and (2) pick an analytical method that can at least meet the minimum sensitivity desired. However, because of the time and money involved, one does not always seek to maximize the amount of sample that is analyzed. Instead, one decides in advance what minimum sensitivity is required to answer the question of concern (e.g. are there levels of immediate concern?) and then calculates how much of the sample needs to be inspected to achieve the desired sensitivity. This is particularly true for air and dust samples, where the analytical methods are proven and capable of achieving very low sensitivities.

Both from a time and money perspective, it would be impossible for EPA to achieve very low sensitivities for every air and dust sample collected in Libby. The difference in time and cost for analyzing a single air sample to a sensitivity of 0.001 s/cc compared to 0.0001 s/cc can be 2 hours versus 8 hours, and $100 versus over $800. When thousands of samples are required over the course of the investigation and cleanup, this would amount to unacceptable delays and unreasonably high sample costs. EPA has sought to tailor the air and dust analyses so that the desired sensitivities answer only the question of concern, reserving the most time consuming and costly sample analyses for only the samples that require very low sensitivities. Table 5-3 presents a summary of typical sensitivities sought and achieved for various types of air and dust samples collected in Libby.

5.2 Soil Sampling and Analysis

Comment [124]: Haystack analysis is a wonderful analogy. Easy to follow, and fits well.

Soil is the most complex medium to analyze for asbestos. The basic reasons for this are simple:

- Unlike air and dust, where there is only a limited amount of non-asbestos material present on the sample preparation that would obscure the presence of asbestos, soil is nearly *all* non-asbestos material – and it is a three dimensional matrix. In crude terms, even when there are relatively high amounts of asbestos in soil, it is often hard to see the asbestos because the *soil itself* gets in the way. A simple analogy is looking for needles in a haystack and trying to estimate how many needles there are in the entire stack. Even if there are thousands of needles, there are many, many more pieces of hay. The lower the number of needles relative to the amount of hay, the harder they are to find. If the entire stack were laid out flat, as with air and dust samples, it would be significantly easier to spot and count the needles.

- Soil is, by nature, a very complex, heterogeneous mixture of minerals and organic materials. This is very different than commercial asbestos products that were specifically produced to consistently contain the same limited ingredients in the same basic proportions. Two soil samples taken near the same location may be drastically different – different colors, different minerals, different grain sizes, and different amounts of organic materials. This makes inspection of the samples in a consistent way difficult. Taking the analogy a step further, it is even harder to look for the needles if the hay is all different – different colors and shapes of hay strands, some things that aren't even hay but aren't needles either, and some hay strands that look a lot like needles.
- Lastly, and perhaps most importantly, the presence and amount of asbestos in Libby soils is highly variable. The asbestos wasn't evenly mixed in at high concentrations, as with a commercial asbestos product, and it wasn't a naturally occurring component of the soils found away from the vermiculite deposit. This means that its presence in Libby is very inconsistent – on both a large scale and a very small scale. On a large scale, for example in a residential yard, LA may be present in certain portions of the yard (where vermiculite was used), but not in another (where it wasn't). On a small scale, even at the size of a few grams in a sample, asbestos may be present in one part of the sample, but not another. If the analyst looks at the wrong part of the sample, he might miss all or most of the asbestos. Or, in the converse, if he looked only at the part with the asbestos, he might conclude the whole sample had that much, when on the average, it had far less. To complete the analogy, imagine you have about fifty complex haystacks to inspect, but only a few have needles, and you can only take the time and money to look at portions of ten or twenty. And in the ones that do have needles, all the needles are in only a small portion of the stacks, different in each one. If one just looked randomly, it would be hard to find the needles, and even harder to accurately estimate the total number of needles in all the stacks.

Most established, standardized analytical methods available for detecting and measuring asbestos in soil were primarily developed using older technologies and for the purpose of analyzing commercial products with high, homogeneous concentrations of asbestos. In general, they were not developed specifically for soils, and coupled with the reasons described above, are not acceptable for accurately measuring lower amounts of asbestos in soils. In fact, the concern regarding asbestos in soil is a relatively new one. In the past, the regulatory and public health focus has been almost exclusively on commercial products.

Because of the suspected widespread existence of contaminated soils in Libby and the highly variable nature of the contamination, the lack of a proven analytical method capable of detecting low concentrations of asbestos in soil presented a serious challenge for EPA. Because of this, EPA placed a great deal of emphasis on determining how to sample soils and how to analyze soil samples. As discussed in Section _____, EPA conducted a multi-year investigation and evaluation of soil analytical techniques called the Performance Evaluation Study (PE Study). The PE Study is discussed in more detail below and discussed in its entirety in the PE Study Data Summary Report (citation). Even with this work, there are still significant uncertainties and limitations to soil analysis, and EPA has not found or developed a *single* analytical approach that can overcome all of the challenges presented by soil. However, EPA has implemented multi-tiered investigation and emergency response cleanup programs designed to help minimize and overcome the uncertainties introduced by these challenges. The next few sections discuss some fundamental concepts of soil sampling and analysis, highlighting some basic things EPA has done in Libby to improve our ability to detect and more accurately estimate LA concentrations in soils.

5.2.1 Soil Sample Collection

Collection of soil samples is more straightforward than collection of air or dust samples. In crude terms, one simply scoops a measure of dirt. There are two basic approaches to soil sampling. *Grab, or discrete,* samples are collected in a single location and are intended to measure the asbestos only at that point. They are advantageous for determining asbestos concentrations in a single, small area, or in an area expected to have consistent, homogenous concentrations of asbestos. *Composite* samples are composed of several sub-samples collected at multiple locations that are mixed together before being analyzed. Composite samples are intended to represent the "average" or typical concentration over an area. Composite samples are valuable for efficiently screening larger areas. This is especially true for areas expected to have inconsistent, highly variable concentrations of asbestos such as Libby.

The same principle applies to the depth of soil samples – samples can be collected at a very specific depth (e.g. 0-1 inch) or across a larger depth interval (e.g. 0-6 inches).

In Libby, EPA has used a combination of grab and composite soil sampling, depending primarily upon the size of the area of interest and the objective of the sample. However, especially for characterizing larger areas such as residential yards, composite samples are used for the vast majority of samples. This is to help overcome the variability in soil asbestos concentrations inherent in Libby and to reduce the number of costly analyses required to screen large areas using grab samples. This approach is also complimentary to quantitative risk assessment, because long-term risks are usually modeled based upon average exposure concentrations over an area and time. However, composite sampling may tend to "mask" particularly contaminated areas, because the sub-sample from that area may be mixed with less contaminated sub-samples before analysis. For this reason, composite sample results must be interpreted carefully, and in many circumstances, it may be prudent to revisit the area and conduct additional sampling on a smaller scale to determine the exact areas and magnitude of contamination.

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5.2.2 Soil Sample Analysis

5.2.2.1 Soil Sample Preparation

Soil samples can be prepared in numerous ways before analysis. Some steps are included simply to put the sample in a size and condition so that it can be analyzed by a particular method, such as mounting soil on a slide for analysis under a microscope. These are specific to the method used for analysis. However, some steps are aimed at making the sample easier to analyze and more homogeneous. Among other things, soil samples can be:

- *Mixed* to make the sample more homogeneous
- *Sieved* to remove large particles that are not of concern
- *Ground* to make the particles smaller and the sample even more homogeneous
- *Ashed* to burn away organic material
- *Chemically washed* to remove organic and other materials
- *Physically manipulated* through various means to try to separate the asbestos from the soil

All of these steps are aimed at addressing the problems inherent to soils discussed above. This generally means making it easier to find and measure the asbestos in the soil. In Libby, EPA has experimented with all of these preparation steps and have used many of them to various degrees as well. The PE Study, discussed in more detail later in the report, has shown that no single preparation step or combination of steps can completely overcome all the challenges of soil samples. However, no matter what analysis method is used in the end, the PE Study and EPA's experiences in the field have consistently shown that preparing Libby samples through mixing, sieving, and grinding is the probably the single most important thing one can do to improve the effectiveness of soil sample analysis. The vast majority of all soil samples in Libby are mixed, sieved, and ground prior to analysis.

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As with indirect preparation of air and dust samples, preparation steps for soil fundamentally affect the nature of the soil sample, so results must be interpreted accordingly.

Comment [125]: Makes me wonder whether grinding doesn't change the size distribution. Seems like this would be e significant concern – perhaps a short paragraph on the effects of sample prep and how you interpret would place the reader at ease.

5.2.2.2 Basic Soil Analytical Technologies

There are three basic technologies for soil sample analysis: optical microscopy, electron microscopy, and spectroscopy. Each can be used with all of the preparation steps bulleted above. In optical microscopy, similar to PCM for air samples, an analyst observes a *small* portion of a soil sample under a polarized light microscope (PLM) and attempts to count or estimate how many asbestos particles are present. In electron microscopy, an analyst observes a *tiny* portion of a soil sample under either a transmission or scanning electron microscope (TEM or SEM) and attempts to count how many asbestos particles are present. In spectroscopy, an energy source such as an X-ray or infrared light is directed at the soil sample and the reflected or transmitted energy is measured. Which portion of the energy is transmitted or reflected, and how much, can show what materials are present, and to a degree, how much of them are present. All three have advantages and disadvantages. Each is discussed briefly below.

<u>PLM</u>

PLM has been used for decades to analyze bulk materials, and to a lesser extent, soils. There are several standardized methods for PLM analysis of soils. Similar to PCM, PLM has a magnification of approximately 100-650x, and as such, cannot distinguish very small particles. Unlike PCM, it can differentiate between asbestos and non-asbestos particles and determine mineralogy to a degree. There are two general variations used in PLM: point counting and visual estimation. Point counting involves quantitative counting of asbestos particles; visual estimation involves more qualitative estimation of the amount of asbestos present. Unlike air and dust samples, no attempt is made to classify particle sizes in the results.

Traditionally, PLM has been widely criticized for its inability to detect concentrations below about 1% and its poor accuracy and precision. This criticism is valid. However, the Libby PE Study has shown that many of the problems associated with PLM are not inherent to the technology, but rather are attributable to how samples are prepared, the specifics of the approved methods, and analyst training. These problems can largely be overcome through better sample preparation, better lab and analyst training, and site-specific measures designed to maximize the technology. If one understands the limitations of PLM, it can be used as an effective analysis and screening technique for soils.

<u>TEM and SEM</u>

TEM and SEM have both been used in the past to analyze bulk materials and soils. There are a few approved, standardized TEM methods for soil analysis, but none for SEM. Both technologies can achieve magnifications of 10,000x or higher. TEM for soil samples works on the same principle as it does for air and dust sampling – the fundamental difference is that large quantities of three dimensional soil must somehow be reduced down to small quantities and placed on a two dimensional surface to be analyzed. SEM is similar. The benefits of SEM and TEM are their high magnification relative to PLM and their ability to clearly distinguish individual and very small fibers. However, this is also the primary drawback of both technologies. To look at such a high magnification, one can only look at a very small portion of the sample. If the sample is heterogeneous, as all soil samples are, this can actually present a greater problem for TEM and SEM (where a tiny portion of the sample is observed) than for PLM (where a larger portion is observed). This is especially true for TEM. The chance of missing particles in the tiny area of the view is high, and the chance of overestimating the amount of asbestos based on this tiny area is also high. This often leads to inconsistent results. Similarly, high amounts of asbestos can overwhelm the microscope and lead to inaccurate estimation of asbestos concentrations. These limitations can be overcome to some degree through improved sample preparation and by looking at larger amounts of soil from each individual sample. However, this is costly and time consuming. Based upon EPA's review of existing methods and research at Libby, neither TEM nor SEM soil analysis has been perfected to a degree where the results are sufficiently accurate, precise, and repeatable to justify the expense and time required. As such, TEM and SEM have not yet been used on a "production scale" to analyze soil samples in Libby.

There are, however, important uses for TEM and SEM in soil. At Libby, EPA has used specialized both TEM and SEM analysis to answer a number of critical questions about LA and to support the PE Study. Update when RI results are in.

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<u>Spectroscopy</u>

There are several spectroscopy technologies. Spectroscopy is particularly valuable for identifying the mineralogy in samples. It cannot differentiate between fibrous and non-fibrous materials. While some work is being done outside of EPA to improve the ability of spectroscopy methods to quantify the amount of asbestos in soils or bulk materials, no methods have been perfected to a degree where the results are sufficiently accurate, precise, and have a low enough sensitivity to outperform other methods. In Libby, spectroscopy methods have been used to screen for the presence of LA in soils on a limited basis, but are generally used for mineralogical identification purposes.

5.2.3 PE Study and Analytical Sensitivities for Soil Analysis

Much more so than for air and dust samples, sensitivities for soil asbestos analyses are driven by the limitations of the analytical methods themselves – the method detection limits. While TEM and SEM soil methods are theoretically capable of achieving very low sensitivities, in practice this has thus far proven unobtainable except in very limited circumstances. So, unlike air and dust samples, where very low sensitivities can be achieved if one can spend the time and money, the lowest amounts of asbestos that can be detected (and reliably quantified) in soil are mostly predetermined by the method. At present, no amount of time or money can overcome this limitation on a scale that would be useful for more than a few samples. This is critical because, by many measures, lower levels of asbestos in soil that may present a health risk are not consistently detectable or accurately quantifiable using the most commonly used soil analytical methods.

In Libby, through the PE Study, EPA has sought to test and improve existing analytical methods for soil, or develop and test new ones, to enable more consistent detection of lower amounts of asbestos than previously achievable.

Summary of PE Study

5.3 State of Science for Soil Analysis?

Not sure about this section, but it would discuss limitations of what we knew in 2000 and what we know now. Tie in to use of visible vermiculite as a trigger (reasonable indicator of LA; saves sample analysis costs; helps to overcome limitations of analytical methods). Why we haven't used other methods (e.g. elutriator).

Comment [126]: If you can add this section it would be great – in the coming years we will refer to these lessons learned, and it would be very helpful to summarize the most important ones here.

5.4 Measurement Units

Because asbestos is measured in several different media, and because there are so many different analytical methods available, there are many different measurement units used for reporting sample results. The units can be a bit misleading and difficult to interpret. As discussed above, air results are typically reported in asbestos structures or fibers per cubic centimeter of air (s/cc or f/cc). To aid in interpreting these results, it may be helpful to convert them to structures per cubic *meter* of air. Human beings typically breathe many cubic meters of air per day, so this measurement unit is more directly relatable to everyday life. Because there are 1,000,000 cubic centimeters in one cubic meter, given a constant concentration of asbestos there will be

1,000,000 times more asbestos structures in a cubic meter of air than in a cubic centimeter of air. So, if a sample result indicated an asbestos concentration of 0.001 s/cc, this would equate to 1000 structures per cubic meter of air. A concentration of 0.001 s/cc seems very small; an equal concentration of 1000 s/m^3 seems considerably larger. However, they represent the same value.

Dust concentrations are typically reported in units of asbestos structures per square centimeter of surface area (s/cm^2). In these units, typical dust concentrations have much "higher" appearing numbers than those in air. For instance, (using round numbers only for a simplistic comparison) a dust concentration of 1000 s/cm^2 might produce air concentrations of 0.01 s/cc. 1000 s/cc seems high, while 0.01 s/cm^2 seems low. However, the two concentrations, and the risks they present, are directly related. This is because at any given time, only a fraction of the dust and asbestos is suspended in the air. Additionally, once disturbed, the asbestos settled on the flat surface is dispersed throughout a large volume of air.

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Soil and bulk material results are usually presented differently than either air or dust. The reporting methods are directly related to the historic use of PLM for measuring asbestos content in commercial materials. For PLM, and some other methods, results are usually presented in terms of the percent of the material (by weight or mass) that is asbestos (e.g. 0.5%). Typical measurable concentrations can range from about 0.001% to greater than 1%. Sometimes the term "trace" is used to describe concentrations lower than 1%. Again, the values often appear "small" and can be misleading. Concentrations on the order of .001% or .01% represent values of tens or hundreds of millions of asbestos structures per *gram* of material. "Trace" could indicate similar amounts. This highlights the difficulty with asbestos soil analysis – it's difficult to detect even millions of these extremely small asbestos structures in a gram of soil. Historically, some asbestos regulations and commercial industry have used 1% for determining which asbestos containing materials are regulated and which are not. This has led to a common perception that materials containing less than 1% are safe and that any values less than 1% are "low." This 1% standard was based primarily on the analytical capabilities of PLM and was not based upon toxicological considerations of what is "safe." Values less than 1% can unquestionably be of health concern (Cook 2004).

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Similar to dust, one might question how millions of structures per gram of soil wouldn't *always* lead to very high concentrations in air and associated high health risks. This is because, like dust, only a fraction of the soil and asbestos is suspended in air when the material is disturbed. And that material is then dispersed through a relatively large volume of air.

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Overall, it's important to understand that the value that is most important is the *air* concentration. Asbestos in air is what is breathed. Air concentrations are the values used to estimate risks in mathematical models used by EPA and others. Whether a material such as dust, soil, or vermiculite contains what one might label as a "small" or "large" amount is not really important. If the asbestos is not released, it is not a health concern. If it is released, then depending on the amount, it can be – no matter how much was present in the material itself. Determining how much asbestos in various media, under various conditions, might be released to air is not a simple correlation and remains a matter of regulatory and scientific debate.

Comment [127]: I like how you back and remind the reader of perspective – what's important and why.

5.5 QA/QC Program

6.0 Site Conceptual Model

A Site Conceptual Model (SCM) is a graphical tool for depicting the various ways humans or animals may come into contact with contaminants in the environment. An SCM presents information on how contaminants enter the environment, how contaminants migrate within the environment, the potential populations that may come into contact with these contaminants, and the "pathways" by which these populations are be exposed. By presenting the potential exposure pathways in a simple format, a situation that may appear extremely complex is reduced to one that is manageable. SCMs are used primarily to ensure that all current and future exposure pathways are thoughtfully considered prior to designing sampling and risk assessment investigations. Separate SCMs are usually prepared for both human health and ecological risks, though at Libby ecological risk is expected to be insignificant and no ecological SCM has been prepared.

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The initial human health SCM for the Libby Asbestos Site was developed prior to EPA sampling activities and was presented in the Phase 1 Quality Assurance Project Plan (EPA 2000). This SCM focused on inhalation exposures of residents and mining workers in Libby and identified two potential sources of asbestos – vermiculite processing related sources (e.g., the former export plant) and vermiculite waste and product sources (e.g., vermiculite insulation).

Based upon information collected during the RI and emergency response cleanup, the human health SCM was expanded and refined in the Supplemental Remedial Investigation Quality Assurance Project Plan (EPA 2005). This SCM further refined the exposure scenarios for residents and included potential exposures of recreational visitors and non-mining workers. It also added a detailed extension of the SCM that was developed for evaluating the efficacy of the emergency response residential/commercial cleanup program. The SCM was further modified slightly for purposes of this report. Figure 6-1 presents the site-wide human health SCM and Figure 6-2 presents the residential/commercial cleanup SCM extension. Each line one can trace from an LA source to an exposure represents a distinct *current or future* exposure pathway of concern. Depending on how one interprets the SCM, there are about 10 major exposure pathways of concern, most with slight variations. Some important *past* exposure pathways are not emphasized because they no longer exist (e.g. vermiculite mining and processing operations have ceased), and some of the pathways presented were also more significant in the past (e.g. outdoor air around the vermiculite processing operations was likely more contaminated in the past). All exposure pathways culminate in inhalation of airborne LA by residents or workers. Other potential exposures to LA, such as ingestion and dermal contact, are thought to be insignificant relative to the health risks from inhalation, as are risks to Libby visitors relative to risks to Libby residents and workers.

The SCM for the Libby Site is particularly important because of the numerous exposure pathways present. To effectively assess and manage the cumulative risks faced by Libby residents and workers, one must understand and *quantify* each component along each exposure pathway. For the remainder of the RI, for simplicity purposes, EPA uses the SCM as an outline for describing the nature and extent of contamination present at the Site.

7.0 OU4 Study Area

During initial actions at Superfund Sites, interested parties often question where the boundaries of the investigation and cleanup will be. However, in most cases, EPA does not establish the limits of a site until *after* the remedial investigation is complete and the extent of the contamination is determined. In some instances, EPA establishes a *study area* prior to or during the remedial investigation. The study area is used to guide future sampling and provide interested parties a general idea of the area subject to Superfund concern. It is not a legally binding site boundary and may change as new information is gathered. EPA established a study area boundary for Libby OU4 at the onset of remedial investigation sampling.

Establishing a study area at the Libby Asbestos Site was not straightforward for two primary reasons. First, the *dominant* mechanism for the spread of contamination was seemingly not transport by air or water. At Libby, people using vermiculite products and wastes, or unknowingly transporting contamination on their clothes or equipment, spread contamination *randomly* over a large area. This means that there is no obvious, large-scale plume or continuous area of contamination that can be used to establish boundaries. Instead, the Site consists of a large, undefined area with pockets of contamination throughout. Second, while the contamination was most concentrated in Libby, the human actions that spread the contamination were not confined only to the immediate Libby area. In some cases, waste materials may have been transported relatively large distances to nearby towns such as Yaak, Eureka, and Kalispell. Many vermiculite workers resided in Troy and other nearby areas. As discussed in Section 3, vermiculite insulation and other vermiculite products were shipped, sold, and used throughout the country, including locations relatively close to Libby. This means that there is no definite boundary where the impacts related to the Libby vermiculite mine cease to exist.

In light of these factors, EPA sought to establish a study area boundary for OU4 that:

- Was based upon the site conceptual model discussed in Section 6 and sought to include an area that addressed all of the exposure pathways.
- Included the vermiculite mine and all former vermiculite processing locations.
- Included the majority of populated, developed areas in and around Libby where vermiculite wastes and products may have been used frequently.
- Included most locations where vermiculite workers resided (with the exception of Troy) and may have transported contaminated dust or equipment.
- Excluded outlying areas that were expected to be relatively free of contamination related directly to the vermiculite mine or vermiculite processing. Any impacts in these areas would likely be isolated in nature and of a scale similar to other parts of the country where vermiculite products may have been used.
- Conformed loosely to the geographic boundaries of the Libby valley.
- Would capture the majority, if not all, of any undiscovered, or immeasurable, plume(s) of contamination that may have been aerially dispersed from the vermiculite mine and/or vermiculite processing operations.
- Was simple to depict and explain.

Deleted: Was based

Deleted: loosely on

Deleted: for the public to understand

The OU4 study area is shown in Figure 7-1. During the CSS and emergency response removal actions, all developed residential and commercial properties within the study area were investigated and subject to potential cleanup (with the exception of those for which an access agreement could not be attained). This represents a total of approximately 3,600 properties out of approximately 4,000 developed properties in the study area. Outside of the study area, properties were presumed to be free of contamination. Properties outside the study area were investigated and/or cleaned up only when specific information was presented that indicated the property might be contaminated, and the contamination was suspected to be directly related to vermiculite mining or processing wastes (e.g. not limited to commercial vermiculite products). There have only been a few of these properties, most just outside the study area along Pipe Creek Road (an area clearly within the general population center of Libby).

Comment [i28]: Clarify – if it's within the gen'l population area, shouldn't it be within the study area?

At this time, the OU4 study area remains valid and is not expected to change significantly. However, an overall site boundary has not yet been established. Two additional investigations must be completed prior to establishing a site boundary:

- The remedial investigation of Troy (OU7) must be completed. MDEQ, working with EPA, has established a study area for the Troy RI, but investigations are not expected to begin until 2006.
- The RI/FS of the mine and mine road (OU3) must be completed. Specifically, it is likely that an aerially dispersed plume, or footprint, of contamination exists around the former mine. The extent and impact of this footprint have not yet been investigated or defined. Current information suggests that areas of concern are limited to forested areas around the mine that are within the OU4 study area (and mostly, if not completely, closed to public access), but additional investigation is warranted. The University of Montana, in cooperation with EPA, is currently planning various investigations aimed at addressing this issue.

The final site boundary will be established in the future based upon the measured extent of contamination within the study areas of Libby and Troy (OU4 and OU7) and the best information available regarding aerially dispersed contamination.

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